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DOI: https://doi.org/10.1016/j.jacme.2016.05.001

Available online at www.sciencedirect.com

ScienceDirect

Journal of Acute Medicine 6 (2016) 29–34

www.e-jacme.com

Original Research

# Analysis of fluid resuscitation in critically injured patients—A central role of saline solutions

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Received 9 March 2016; revised 27 April 2016; accepted 17 May 2016
Available online 14 June 2016

**Abstract**

*Objective*: Multiple injury patients are mostly in the productive age group and are at high risk of dying by exsanguination. In this study, the focus was set on fluid resuscitation, death, and outcome of critically injured patients.
*Methods*: In total, 2956 patients were included in this sample. The inclusion criteria were age $\geq$ 16 years and injury severity score $\geq$ 16. The sample was divided into groups of patients who died within 72 hours of injury and those who survived. Differences between the groups were measured by analysis of variance and Kruskal–Wallis test for parametric data. Independent predictors were analyzed by logistic regression, and the predictive quality was analyzed by receiver operating curves. The given volumina were normalized according the Trauma Score—Injury Severity Score of each patient. All analyses were performed using SPSS.
*Results*: The binary logistic regression revealed the given amount of saline solutions and colloids within the first 48 hours as independent predictors of survival ($p < 0.001$, $p = 0.003$). The receiver operating curves revealed that the area under the curve increased as a function of time, and after 48 hours it was 0.825 for saline solutions and 0.702 for colloids for survival.
*Conclusion*: Fluid resuscitation does not negatively influence survival; however, the amount of fluids given within the first 24 hours after trauma is an independent predictor of survival with very good predictive quality.


*Keywords:* mortality; multiple trauma; resuscitation; saline solutions

## 1. Introduction

Critically injured patients are at high risk of dying by exsanguination and of developing systemic inflammatory response syndrome. Trauma-induced coagulopathy is a multifactorial failure of the coagulation system to prevent ongoing bleeding. In critically injured patients, derangement of the coagulatory cascade is common, and is associated with a poor outcome by exsanguination and later inadequate resuscitation-induced complications.[1–3] Each attempt at correction may lead to further derangement of the coagulatory cascade, and to inadequate resuscitation-related organ dysfunction and immunological overactivation of the systemic inflammatory response syndrome. Inadequate resuscitation-related bleeding leads not only to a loss of oxygen carriers, but also to a loss of coagulatory factors and the complementary system, shutting down the humoral immunity and opening the door for environmental pathogens. Inadequate additional resuscitation attempts further dilute the residual concentration of coagulatory and complement factors, handicapping blood coagulation and humoral immunity. Clear resuscitation protocols for the use of crystalloids are lacking, and blood

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http://dx.doi.org/10.1016/j.jacme.2016.05.001

parameters are measured continuously during resuscitation, mirroring the patient's reality in the past. Therefore, a descriptive cohort study in a retrospective manner, to provide some information on the validity of the different resuscitation fluids used in critically injured patients, and to provide orientation points for the future improvement of damage control resuscitation, was ruled out.

## 2. Methods

### 2.1. Patient sample

A total of 2956 critically injured patients admitted to the resuscitation room of the University Hospital of Zürich (Switzerland) during the period 1996–2013 were included in this retrospective cohort study. The inclusion criteria were an injury severity score (ISS) of ≥16 points, age ≥16 years, and admission within at least 24 hours of incurring multiple injuries. The patient sample was divided into two groups (Table 1) comprising patients who died within the first 72 hours and those who survived longer than the first 72 hours. All patient data were collected retrospectively. The patient data were retrieved from patient records with the approval of the local institutional review board, according to the University of Zürich institutional review board guidelines and the World Medical Association Declaration of Helsinki; the study was conducted according to our institutional guidelines for good clinical practice (Ethics Committee of the University Hospital of Zürich Permission: *"Retrospektive Analysen in der Chirurgischen Intensivmedizin"*; permission number: St.V. 01-2008).

Table 1
Patient sample.

| Admission | Exitus < 72 h | Survival > 72 h | Total | *p* |
|---|---|---|---|---|
| *N* | 615 | 2341 | 2956 | <0.001[a] |
| Age (y) | 51.2 ± 22.1 | 42.8 ± 18.4 | 44.5 ± 19.6 | <0.001[b] |
| Sex (male/female) | 436/179 | 1732/609 | 2168/788 | <0.001[a] |
| T admission (C°) | 34.5 ± 2.6 | 35.7 ± 1.5 | 35.5 ± 1.8 | <0.001[b] |
| BMI (kg/m$^2$) | 25.3 ± 4.6 | 25.0 ± 4.4 | 25.0 ± 4.4 | 0.425[b] |
| Shock (ATLS) | 2.1 ± 1.1 | 1.4 ± 0.7 | 1.6 ± 0.9 | <0.001[b] |
| GCS | 5.9 ± 4.0 | 11.0 ± 4.5 | 9.9 ± 4.9 | <0.001[b] |
| ISS | 36.9 ± 17.0 | 26.4 ± 12.5 | 28.6 ± 14.2 | <0.001[b] |
| NISS | 50.8 ± 16.6 | 35.0 ± 15.4 | 38.2 ± 17.0 | <0.001[b] |
| AIS head | 4.1 ± 1.7 | 2.6 ± 1.9 | 2.9 ± 2.0 | <0.001[b] |
| AIS face | 0.4 ± 1.0 | 0.6 ± 1.0 | 0.6 ± 1.0 | 0.002[b] |
| AIS thorax | 1.6 ± 1.8 | 1.7 ± 1.6 | 1.7 ± 1.7 | 0.330[b] |
| AIS abdomen | 1.0 ± 1.8 | 1.0 ± 1.7 | 1.0 ± 1.7 | 0.990[b] |
| AIS spine | 0.5 ± 1.2 | 0.9 ± 1.4 | 0.8 ± 1.4 | <0.001[b] |
| AIS extremities | 1.1 ± 1.4 | 1.5 ± 1.4 | 1.4 ± 1.5 | <0.001[b] |
| AIS pelvis | 0.6 ± 1.2 | 0.6 ± 1.2 | 0.6 ± 1.2 | 0.471[b] |
| AIS skin | 0.4 ± 0.8 | 0.5 ± 0.8 | 0.54 ± 0.8 | <0.001[b] |
| APACHE II | 23.8 ± 7.4 | 12.6 ± 7.7 | 14.9 ± 8.9 | <0.001[b] |
| TRISS | 0.501 ± 0.296 | 0.817 ± 0.234 | 0.752 ± 0.279 | <0.001[b] |

For all nonparametric data, Kolmogorov–Smirnov was $p > 0.05$.
AIS = Abbreviated Injury Scale; APACHE = Acute Physiology and Chronic Health Evaluation; ANOVA = analysis of variance; ATLS = Advanced Trauma Life Support; BMI = body mass index; ISS = injury severity score; GCS = Glasgow Coma Scale; NISS = New Injury Severity Scale; SD = standard deviation; TRISS = Trauma Score—Injury Severity Score.
[a] $\chi^2$, mean ± SD.
[b] ANOVA.

### 2.2. Diagnostic protocol

Unstable patients underwent resuscitative procedures according to the Advanced Trauma Life Support (ATLS) standards of the American College of Surgeons, and life-saving surgery was performed according to Definitive Surgical Trauma Care (by International Association for Trauma Surgery and Intensive Care).[4,5] Hemodynamically stable patients received diagnoses according to the clinical findings or a whole-body computed tomography scan in uncertain situations. Hemodynamically unstable patients received focus-oriented diagnostics with immediate problem solving, according to the ATLS and Definitive Surgical Trauma Care guidelines.

### 2.3. Scoring systems

The Acute Physiology and Chronic Health Evaluation II score was used to evaluate the overall physiological impairment of the patient at admission.[6] The ISS and the New Injury Severity Scale were used to define the severity of trauma.[7,8] The Abbreviated Injury Scale (AIS; 2005 version) was used to describe injuries in specific anatomical regions.

The Trauma Score—Injury Severity Score (TRISS) was used to analyze the probability of death in the patient sample.[9]

### 2.4. Hypothetical sources of bias

All patients were selected retrospectively. Documentation of all parameters followed the Good Clinical Practice guidelines. Several persons collected the data under the guidance of the personnel selecting the patients. The 17-year time span could have led to a bias in time-related changes in the treatment of trauma-associated coagulopathy; however, the definition of systemic inflammatory response syndrome and sepsis remained the same, as well as the measurement of quantities. The scores and values were calculated using a single Excel sheet (Office 2010; Microsoft, Redmond, WA, USA).

### 2.5. Statistical analysis

Data are presented as the mean ± standard deviation for continuous variables and as percentages for categorical variables. Cases with an incomplete data set were analyzed by missing completely at random test. The two-tailed Kolmogorov–Smirnov test was used for testing normality, and if $p > 0.05$, the data were considered as normally distributed. Categorical data were analyzed using the $\chi^2$ and Kruskal–Wallis test; the one-way analysis of variance was used for continuous normally distributed data. Results were considered statistically significant at $p < 0.05$. The predictive quality of the different fluids was reported as the area under the receiver operator characteristic (ROC) curve (AUC). The independent predictivity was analyzed by binary logistic regression; the goodness of fit for the logistic regression was given by the Hosmer–Lemeshow test and considered as good if $p > 0.05$. The data were considered as independent predictive variables

if $p < 0.05$. The data for the analysis of death were normalized according to the TRISS. The data were analyzed using IBM SPSS software (Version 22.0; IBM Corp., Armonk, NY, USA).

## 3. Results

### 3.1. Patient sample

The patient group comprising those who died within 72 hours was significantly smaller than the patient group surviving the first 72 hours (615 patients vs. 2341 patients, $p < 0.001$). There were significantly more male (2168) than female (788) patients in both groups (male vs. female; $p < 0.001$). The patients who died within the first 72 hours were significantly older than those who survived the first 72 hours (51.2 ± 22.1 years vs. 42.8 ± 18.4 years, respectively; $p < 0.001$; Table 1). The patients who died within the first 72 hours were significantly more severely injured (ISS, 36.9 ± 17.0 vs. 26.4 ± 12.5, $p < 0.001$; New Injury Severity Scale, 50.8 ± 16.6 vs. 35.0 ± 15.4; $p < 0.001$; Table 1). A heterogeneous distribution was observed for the AIS values (Table 1). The physiological state at admission was generally worse in patients who died within the first 72 hours, as reflected by the Acute Physiology and Chronic Health Evaluation II score (23.8 ± 7.4 vs. 12.6 ± 7.7; $p < 0.001$; Table 1). The probability of survival predicted by TRISS was significantly lower in the group of patients who died within the first 72 hours (0.501 ± 0.296 vs. 0.817 ± 0.234; $p < 0.001$; Table 1). The injury pattern showed a heterogeneous distribution; interestingly, two peaks were observed in the AIS head, indirectly indicating an important role for craniocerebral injuries in multiple injury patients (Table 2).

### 3.2. Distribution of the administered volume

The analysis showed significant differences in the observed distribution of totally given fluid volume, saline solutions, and colloids mainly after 48 hours (Table 3). No significant differences were observed in transfused erythrocytes, thrombocytes, and fresh frozen plasma (Table 4) in this patient sample. After normalization of the data according to the TRISS, almost all administered volumes were found to be significantly different between the groups (Table 4).

Table 2
Distribution of the injury pattern according the respective AIS score of the patient sample.

| AIS | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Head | 23.7 | 6.5 | 7.8 | 13.8 | 20.5 | 25.2 | 2.5 |
| Face | 70.4 | 5.3 | 12.9 | 9.4 | 1.9 | 0.1 | 0 |
| Thorax | 44.9 | 4.3 | 4.2 | 29.1 | 10.3 | 7.2 | 0.1 |
| Abdomen | 67.8 | 4.5 | 5.5 | 6.2 | 9.6 | 6.4 | 0 |
| Spine | 68.9 | 0.8 | 11.4 | 10.4 | 4.6 | 3.7 | 0.2 |
| Extremities | 44.3 | 4.9 | 20.7 | 19.2 | 7.3 | 1.9 | 0.7 |
| Pelvis | 76.3 | 3.8 | 1.6 | 11.5 | 1.8 | 1 | 0 |
| Soft tissue | 62 | 21.7 | 10.6 | 4 | 1.4 | 0.3 | 0 |

Data are given as percentage of the respective AIS anatomical region.
AIS = Abbreviated Injury Scale.

### 3.3. Predictive quality of volume therapy for survival

The analysis by ROC showed highest values of AUC for the saline solutions (0.661 at admission, 0.729 after 24 hours, and 0.763 after 48 hours; Table 5). Normalization of the data according to the TRISS confirmed the findings from Table 5, the AUCs increased (saline solutions: 0.735 at admission, 0.794 after 24 hours, and 0.825 after 48 hours; Table 6).

### 3.4. Independent volume predictors of survival

The binary logistic regression analysis revealed, in both non-TRISS-normalized and TRISS-normalized data sets, the saline solutions and colloids administered within the first 48 hours as the most significant predictors of survival (Tables 7 and 8). However, the regression analysis for survival revealed a Hosmer–Lemeshow $p$ value of <0.05 (Tables 7 and 8). The analysis of injury pattern revealed the craniocerebral trauma as an independent predictor of death in this patient sample, with a very high odds ratio (Table 9).

### 3.5. Outcome

According to hospitalization and intensive care unit stay, the duration of ventilation and the sepsis rate were significantly higher in the group of patients who survived the first 72 hours (Table 10).

Table 3
Administration of the different volumes at admission, and 24 hours and 48 hours after admission.

| Volume type | Exitus | Survival | Total | $p$ |
|---|---|---|---|---|
| Total at admission (mL) | 928 ± 1114 | 1324 ± 1220 | 1302 ± 1217 | **0.019** |
| Total at 24 h (mL) | 9225 ± 12,015 | 10,867 ± 6206 | 10,778 ± 6653 | 0.075 |
| Total at 48 h (mL) | 11,127 ± 14,643 | 14,681 ± 8110 | 14,489 ± 8619 | **0.003** |
| Saline solutions at admission (mL) | 592 ± 733 | 940 ± 1201 | 921 ± 1183 | **0.036** |
| Saline solutions at 24 h (mL) | 4987 ± 5482 | 7189 ± 3673 | 7070 ± 3822 | **<0.001** |
| Saline solutions at 48 h (mL) | 6069 ± 7148 | 10,200 ± 9308 | 9975 ± 9249 | **<0.001** |
| Colloids at admission (mL) | 350 ± 570 | 426 ± 631 | 422 ± 628 | 0.392 |
| Colloids at 24 h (mL) | 2752 ± 3021 | 3369 ± 2526 | 3336 ± 2557 | 0.082 |
| Colloids at 48 h (mL) | 3244 ± 3662 | 4503 ± 3529 | 4435 ± 3546 | **0.010** |
| EC at 24 h (units) | 5.04 ± 8.5 | 6.05 ± 10.4 | 6.0 ± 10.4 | 0.497 |
| EC at 48 h (units) | 5.8 ± 9.5 | 7.0 ± 11.5 | 6.9 ± 11.4 | 0.474 |
| TC at 24 h (units) | 3.1 ± 8.6 | 3.6 ± 9.7 | 3.6 ± 9.7 | 0.696 |
| TC at 48 h (units) | 3.5 ± 9.2 | 4.7 ± 16.2 | 4.7 ± 15.9 | 0.585 |
| FFP at 24 h (units) | 4.7 ± 8.7 | 5.4 ± 10.3 | 5.3 ± 10.2 | 0.671 |
| FFP at 48 h (units) | 5.3 ± 10.1 | 6.3 ± 12.0 | 6.3 ± 11.9 | 0.563 |

In bold: $p < 0.05$.
Data are given as mean ± SD. Kolmogorov–Smirnov $p > 0.05$ for all groups. ANOVA was used for continuous normally distributed data.
ANOVA = analysis of variance; EC = erythrocyte concentrate; FFP = fresh frozen plasma; SD = standard deviation; TC = platelet concentrate.

Table 4
TRISS-normalized data, according to Table 3.

| Volume type | Exitus | Survival | Total | *p* |
|---|---|---|---|---|
| Total at admission (mL) | 605 ± 710 | 864 ± 976 | 821 ± 943 | **<0.001** |
| Total at 24 h (mL) | 5006 ± 6693 | 7408 ± 4693 | 7244 ± 4892 | **<0.001** |
| Total at 48 h (mL) | 5463 ± 8264 | 10,201 ± 6391 | 9928 ± 6603 | **<0.001** |
| Saline solutions at admission (mL) | 402 ± 529 | 668 ± 1050 | 632 ± 999 | **<0.001** |
| Saline solutions at 24 h (mL) | 2893 ± 3616 | 5469 ± 4396 | 5307 ± 4396 | **<0.001** |
| Saline solutions at 48 h (mL) | 3222 ± 4529 | 7684 ± 7435 | 7430 ± 7373 | **<0.001** |
| Colloids at admission (mL) | 265 ± 408 | 291 ± 455 | 287 ± 449 | 0.458 |
| Colloids at 24 h (mL) | 1363 ± 1580 | 2209 ± 2039 | 2158 ± 2024 | **<0.001** |
| Colloids at 48 h (mL) | 1568 ± 2012 | 2882 ± 2481 | 2812 ± 2476 | **<0.001** |
| EC at 24 h (units) | 1.9 ± 6.4 | 2.43 ± 5.6 | 2.3 ± 5.8 | **0.045** |
| EC at 48 h (units) | 1.8 ± 6.4 | 3.0 ± 8.4 | 2.7 ± 8.0 | **0.004** |
| TC at 24 h (units) | 0.8 ± 4.2 | 1.3 ± 4.7 | 1.2 ± 4.6 | **0.030** |
| TC at 48 h (units) | 0.8 ± 4.3 | 1.6 ± 5.4 | 1.4 ± 5.2 | **0.003** |
| FFP at 24 h (units) | 1.3 ± 5.3 | 2.0 ± 5.4 | 1.8 ± 5.4 | **0.006** |
| FFP at 48 h (units) | 1.2 ± 5.0 | 2.3 ± 6.2 | 2.1 ± 6.0 | **<0.001** |

In bold: $p < 0.05$.
EC = erythrocytes; FFP = fresh frozen plasma; TC = thrombocytes; TRISS = Trauma Score—Injury Severity Score.

## 4. Discussion

Fluid resuscitation, oxygen carrier replacement, and correction of trauma-associated coagulopathy are the key issues in initial resuscitation of multiple injury patients. Hopefully, the initial approach of inserting as much fluid as possible into the circulatory system of a multiple injury patient belongs to the past. The approach of damage control resuscitation is being used at present.[10] In this descriptive retrospective cohort study, analysis of resuscitation volumina revealed significant differences almost in all groups after TRISS normalization; these data are certainly a function of time determined by the survival as the outcome factor. The amount of volume applied at admission seems rationally to be the most important factor because all patients were still alive and the rescue time was extremely short. The patient who died within the first 72 hours received at admission significantly less saline solutions, the significance was increased by the normalization to TRISS. These findings are reflected by the ROC analysis; after TRISS normalization, the highest predictive quality for survival was reflected by the saline solutions after 48 hours. The predictive quality increased (AUC) as a function of time, however, was statistically distorted by losing patients within this time. Alternatively, the binary logistic regression analysis revealed the applied saline solution as an independent predictor of survival over 48 hours. Taken together, a central role of saline solutions in resuscitation of multiple injury patients within the first few hours, rather than the totally applied volume within the first 24 hours, might be postulated, as depicted by the raw and TRISS-normalized data. This fact might point to the need for a more aggressive resuscitation strategy based on saline solutions in the preclinical setting. It cannot be depicted by the collected data at what time and how much volume has to be given; it can only be shown that the initial fluid management after multiple traumas is very important for the patient's outcome. Other resuscitation supports such as erythrocytes, thrombocytes, and fresh frozen plasma had no predictive significance in this patient sample. There are no guidelines for the initial resuscitation in the literature. ATLS recommends permissive hypotension according to blood pressure and not more than 2 L of warm saline immediately as a standard. Overflooding the patient with warm saline leads to additional

Table 5
ROC analysis giving the values for AUC according to the survival of patients.

| Volume | Admission | 24 h | 48 h |
|---|---|---|---|
| Total | 0.641 | 0.673 | 0.714 |
| Saline solutions | 0.661 | 0.729 | 0.763 |
| Colloids | 0.541 | 0.603 | 0.627 |
| EC | — | 0.555 | 0.557 |
| TC | — | 0.511 | 0.519 |
| FFP | — | 0.539 | 0.547 |

EC, TC, and FFP are not given preclinically.
EC = erythrocytes; FFP = fresh frozen plasma; TC = thrombocytes.

Table 6
TRISS-normalized data, according to Table 5.

| Volume | Admission | 24 h | 48 h |
|---|---|---|---|
| Total | 0.728 | 0.746 | 0.770 |
| Saline solutions | 0.735 | 0.794 | 0.825 |
| Colloids | 0.567 | 0.683 | 0.702 |
| EC | — | 0.591 | 0.593 |
| TC | — | 0.511 | 0.520 |
| FFP | — | 0.550 | 0.559 |

EC, TC, and FFP are not given preclinically.
EC = erythrocytes; FFP = fresh frozen plasma; TC = thrombocytes; TRISS = Trauma Score—Injury Severity Score.

Table 7
Binary logistic regression for death at <72 hours.

| Volume type | Wald | *p* |
|---|---|---|
| Total at admission (mL) | 0.047 | 0.829 |
| Total at 24 h (mL) | **10.583** | **<0.001** |
| Total at 48 h (mL)s | 1.090 | 0.296 |
| Saline solutions at admission (mL) | 0.095 | 0.758 |
| Saline solutions at 24 h (mL) | 0.963 | 0.326 |
| Saline solutions at 48 h (mL) | **19.972** | **<0.001** |
| Colloids at admission (mL) | 0.011 | 0.915 |
| Colloids at 24 h (mL) | 1.834 | 0.176 |
| Colloids at 48 h (mL) | **9.130** | **0.003** |
| EC at 24 h (units) | 3.730 | 0.053 |
| EC at 48 h (units) | 2.833 | 0.092 |
| TC at 24 h (units) | 0.949 | 0.330 |
| TC at 48 h (units) | 0.137 | 0.712 |
| FFP at 24 h (units) | 0.916 | 0.339 |
| FFP at 48 h (units) | 0.766 | 0.381 |

In bold: $p < 0.05$.
Hosmer–Lemeshow test: $\chi^2$ 65.797, $p$ <0.001.
EC = erythrocytes; FFP = fresh frozen plasma; TC = thrombocytes.

Table 8
TRISS-normalized data, according to Table 7.

| Volume type | Wald | p |
|---|---|---|
| Total at admission (mL) | 0.724 | 0.395 |
| Total at 24 h (mL) | **9.036** | **0.003** |
| Total at 48 h (mL) | 2.698 | 0.101 |
| Saline solutions at admission (mL) | 1.164 | 0.281 |
| Saline solutions at 24 h (mL) | 2.380 | 0.123 |
| Saline solutions at 48 h (mL) | **19.277** | **<0.001** |
| Colloids at admission (mL) | 0.698 | 0.403 |
| Colloids at 24 h (mL) | 1.755 | 0.185 |
| Colloids at 48 h (mL) | **11.755** | **<0.001** |
| EC at 24 h (units) | 3.257 | 0.071 |
| EC at 48 h (units) | 2.518 | 0.113 |
| TC at 24 h (units) | 3.459 | 0.063 |
| TC at 48 h (units) | 1.019 | 0.313 |
| FFP at 24 h (units) | 0.005 | 0.942 |
| FFP at 48 h (units) | 0.003 | 0.953 |

In bold: $p < 0.05$.
Binary logistic regression for the death at <72 hours. Hosmer–Lemeshow test: $\chi^2$ 19.976, $p = 0.01$.
EC = erythrocytes; FFP = fresh frozen plasma; TC = thrombocytes; TRISS = Trauma Score—Injury Severity Score.

Table 9
Binary logistic regression of the injured anatomical regions and their impact on survival.

| Admission | Odds ratio | 95% CI | p |
|---|---|---|---|
| AIS head | 1.775 | 1.595–1.976 | <0.001 |
| AIS face | 0.845 | 0.733–0.974 | 0.020 |
| AIS thorax | 1.068 | 0.967–1.180 | 0.196 |
| AIS abdomen | 1.005 | 0.904–1.117 | 0.925 |
| AIS spine | 1.017 | 0.915–1.129 | 0.759 |
| AIS extremities | 0.833 | 0.740–0.938 | 0.002 |
| AIS pelvis | 1.084 | 0.936–1.256 | 0.281 |
| AIS skin | 0.956 | 0.779–1.174 | 0.670 |

Significant if $p < 0.05$. Craniocerebral injury was found to be an independent predictor of death.
AIS = Abbreviated Injury Scale; CI = confidence interval.

anemia in a bleeding patient, and probably to further dilution of blood plasma favoring trauma-associated coagulopathy.[11] By contrast, hypoperfusion promotes acidosis, and a severe acidosis (pH 7.1) inhibits thrombin generation and accelerates fibrinolysis, resulting in ongoing bleeding.[12,13] TRISS normalization of the presented data pointed to a positive effect of saline solutions in trauma patients. There is growing evidence that very early administration of fresh frozen plasma and erythrocytes in trauma patients can help avoid trauma-associated coagulopathy.[14] The descriptive nature of this study may not provide clear guidance for fluid resuscitation; however, it provides clear evidence for the initial volume and especially for saline solutions given at the trauma scene. This might lead to the normalization of the resuscitation protocols according to ISS or better according to the Berlin Definition of Polytrauma.[7,15]

Table 10
Outcome of the patient sample.

| Outcome | Exitus at <72 h | Survival at >72 h | p |
|---|---|---|---|
| Time to scene (h) | 2.0 ± 4.6 | 5.8 ± 28 | 0.001 |
| Hospitalization (d) | 1.6 ± 2.0 | 21.6 ± 19.8 | <0.001[a] |
| Intensive care (d) | 1.2 ± 1.6 | 10.6 ± 11.3 | <0.001[a] |
| Ventilation (d) | 1.3 ± 1.5 | 6.6 ± 9.0 | <0.001[a] |
| Sepsis (%/*N*) | 1/6 | 19/445 | <0.001[b] |
| Death (d) | 0.7 ± 0.9 | 11.1 ± 11.7 | <0.001[a] |
| Death (%/*N*) | 100/614 | 10/234 | <0.001[b] |

Data are given as mean ± SD. Kolmogorov–Smirnov >0.05 for nonparametric data.
ANOVA = analysis of variance; SD = standard deviation.
[a] ANOVA.
[b] Kruskal–Wallis H test for parametric data.

### 4.1. Limitations of the study

The retrospective character and nature of multiple injury patients lead to a treatment bias that roots in the craniocerebral injury. In these cases where the craniocerebral injury was leading the infusion therapy was performed with lower amounts of crystalloids (Tables 2 and 9). This fact was tried to incorporate this fact in this study by the normalization to the TRISS.

## 5. Conclusion

Fluid resuscitation does not negatively influence survival; however, the amount of fluids given within the first 24 hours after trauma is crucial for the survival of multiple injury patients.

## Conflicts of interest

All contributing authors declare no conflicts of interest.

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